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SALINITY INVESTIGATION OF GRAND VALLEY AND
GUNNISON RIVER, 1962

PUBLIC HEALTH SERVICE, DENVER, COLORADO

1962

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16. Abstracts The results of a two-phase survey of the water of the Colorado River in the Grand Valley area and of the water of the Gunnison River are presented. The first phase of the Grand Valley survey was conducted during the nonirrigation season and included the area from Cameo, Colorado, to below Moab, Utah; the second phase was conducted during the irrigation season and included the area from Cameo downstream to Westwater, Utah. Flow data is reported, detailed information on total dissolved solids in the waters is given, and the relative significance of the sources causing the increase in total dissolved solids in these waters is evaluated.			
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APR 1 TO } IRRIGATION
NOV. 1 } SEASON

SUMMARY AND CONCLUSIONS

SUMMARY

Grand Valley Area: The survey of the Grand Valley area was carried out in two phases. The first phase was from February 19, to March 3, 1962 during the non-irrigation season and included the Colorado River from Cameo, Colorado, above Grand Junction, to below Moab, Utah. (See Figure 2). The second phase was from August 6, through 18, 1962, during the irrigation season, and included the area from Cameo downstream to Westwater, Utah, near the Colorado-Utah state line. (See Figure 3).

Survey results show that total dissolved solids concentrations in the Colorado River increased from 550 mg/l at Cameo to 760 mg/l at Westwater, Utah during the February phase of the survey. During August the total dissolved solids increased from 470 mg/l to 960 mg/l in the same reach of the river.

During February 1962, total dissolved solids loadings in the Colorado River increased from 6.60 million lbs/day at Cameo to 13.50 million lbs/day at Westwater with the Gunnison River system contributing 4.10 million lbs/day of the increase. During the August phase of the survey, total dissolved solids loadings in the Colorado River were 8.12 million lbs/day at Cameo and increased to 17.58×10^6 lbs/day at Westwater. The Gunnison River contributed 5.16 million lbs/day and surface irrigation return drains contributed 1.94 million lbs/day.

Sulfate was the principal ion of all the chemical constituents comprising total dissolved solids in the river during these studies. Sulfate concentrations in the Colorado River during the February survey increased from 130 mg/l at Cameo to 330 mg/l at Westwater, while during August the increase was from 110 mg/l at Cameo to 430 mg/l at Westwater. Sulfate loadings in the river during February were 1.60 million lbs/day at Cameo and increased to 5.90

million lbs/day at Westwater, with the Gunnison River contributing 2.30 million lbs/day. During August there were 2.00 million lbs/day at Cameo, and increased to 7.90 million lbs/day at Westwater, Utah. The Gunnison River contributed 2.55 million lbs/day, while 2.03 million lbs/day were carried to the river in irrigation surface return drains.

Municipal and industrial effluents contributed less than one percent of the total maximum solids increase in the Colorado River as it flowed through the Grand Valley area during both surveys. The principal contributing sources of salinity (total dissolved solids) to the Colorado River in the Grand Valley area were return flows from irrigation, and the Gunnison River, which receives return flows from irrigated areas too.

Gunnison River Basin: The survey of the Gunnison River was carried out August 27 through September 8, 1962. A large increase in total dissolved solids and sulfates was noted where the Gunnison River and its tributaries pass through irrigated agricultural areas.

The Uncompahgre River is a tributary of the Gunnison River. During the survey period, total dissolved solids concentrations in this river increased from 300 mg/l above irrigated areas, to 2,030 mg/l at its mouth. The TDS loadings increased from 0.08 million lbs/day, to 1.96 million lbs/day over the same reach of the river. Sulfates increased from 200 mg/l to 1140 mg/l, and 0.05 million lbs/day to 1.10 million lbs/day in this reach of the Uncompahgre River.

The North Fork of the Gunnison River contained a total dissolved solids concentration of 90 mg/l and a loading of 0.10 million lbs/day above irrigated areas. These values increased to 1,640 mg/l and 0.80 million lbs/day respectively at the mouth, below irrigated areas. In this same reach of river, sulfate concentrations increased from 10 mg/l to 920 mg/l and sulfate loadings increased from 0.009 million lbs/day to 0.44 million lbs/day.

The Gunnison River main-stem above irrigated areas contained a concentration of 120 mg/l and a loading of 0.63 million lbs/day of total dissolved solids, and 20 mg/l, 0.15 million lbs/day of sulfates concentration and loading respectively during the survey period. Below the irrigated area and the mouths of the North Fork and Uncompahgre Rivers, the Gunnison River contained 1,610 mg/l and 5.60 million lbs/day of total dissolved solids concentration and loading respectively, and 900 mg/l and 3.2 millions lbs/day of sulfates.

Municipal and industrial sources contributed less than one percent of the total maximum solids measured in the Gunnison River main-stem during the August-September 1962 study in the Gunnison River Basin.

CONCLUSIONS

These studies indicated that the major contributor of total dissolved solids to the Colorado River in the Grand Valley and Gunnison River Basin area was return water from irrigation processes. Sulfate was the major component in total dissolved solids build-up. There was definitely an addition of chemicals through irrigation processes and concentration increases were not due to just flow depletion.

Less than one percent of total dissolved solids increase was due to municipal and industrial sources.

INTRODUCTION

In August 1960, studies were run on the Colorado main-stem in the Grand Junction, Colorado and Moab, Utah areas. These studies were primarily to determine the effect that uranium mills in these areas had on the

river.^{1/ 2/}

Although chemical data obtained during these studies was limited, it was noted that total dissolved solids and sulfate concentrations were very high in the stretch of the Colorado River between Grand Junction, Colorado and Moab, Utah. Total dissolved solids were 1,380 mg/l and 1,835 mg/l at Grand Junction and Moab respectively, while sulfates were 525 mg/l and 849 mg/l respectively at the two points. It was also noted that the total dissolved solids and sulfate concentrations of 1,700 mg/l and 910 mg/l respectively were present in the Gunnison River. Because of these findings, it was proposed to further study the salinity (total dissolved solids) problem in the Grand Valley area and Gunnison River Basin. Two studies were recommended for the Grand Valley area to compare irrigation and non-irrigation seasons, while a single study of the Gunnison River Basin was prepared, to take place during the irrigation season. The objectives of the Grand Valley and Gunnison River Basin studies of 1962 were to (1) develop detailed information on total dissolved solids in these two areas, and (2) attempt to define and evaluate the relative significance of the sources causing the increase in total dissolved solids in these areas.

1/ Stream Studies in Vicinity of Uranium Mills, I. Area at Grand Junction, Colorado. August 1960. Department of HEW, PHS, CRBP, Denver, Colorado.

2/ Stream Studies in Vicinity of Uranium Mills, II. Area at Moab, Utah. Ibid.

COLORADO RIVER IN THE GRAND VALLEY OF COLORADO-UTAH

Two separate surveys are reported herein, both of which were carried out on a stretch of the main stem of the Colorado River above and below its intersection of Colorado-Utah state line. These surveys were carried out during the winter and summer seasons of 1962. The winter survey included a 155 mile stretch of the main stem of the Colorado River from the town of Cameo, Colorado, 30 miles upstream of Grand Junction, Colorado, downstream to a point approximately 17 miles below Moab, Utah. The summer survey included the reach from Cameo, Colorado, downstream to Westwater, Utah, covering a 73 mile stretch of the river. The Gunnison River enters the Colorado in the stretch of river covered by both surveys, while the Dolores River enters the stretch covered by the winter survey.

The semi-arid area through which the Colorado River flows, and in which the "grand valley" is located, gets less than 10 inches of precipitation on normal years. The annual snowfall of 20 inches, coupled with nearly 200 days of growing season, are conducive to diversified, intense irrigation farming in the area. The elevation of irrigable land in grand valley is 4,700 feet above mean sea level.

Extensive irrigation is practiced in grand valley. Approximately half of the 85,000 acres now under irrigation were irrigated in 1886 by the Grand Valley Irrigation Company through the Grand Valley Canal and its system. In 1917, the Grand Valley Diversion Dam, constructed by the U. S. Bureau of Reclamation, began diverting water to double the irrigated acreage. This water is carried through the Government Highline Canal and Orchard Mesa Canal to the irrigated lands.^{1/}

^{1/} Reclamation Project Data, Grand Valley Project, U. S. Dept. of the Interior, Bureau of Reclamation.

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The Gunnison River is partially diverted to the Redland Power Canal and is used to generate power in a hydro-plant. The power plant effluent enters the Colorado River approximately 3 miles downstream of the mouth of the Gunnison in Grand Junction, Colorado. Some water is extracted from the Redland Canal for irrigation.

The economy of this region depends heavily on the agricultural crops grown on the irrigated land. Some of the crops grown in this area are alfalfa, potatoes, sugar beets, corn, peaches and onions. Lumber and wood processing industries and mining and mineral processing plants also contribute to the economy of the area.^{2/ 3/}

CONDUCT OF SURVEYS

The winter and summer surveys of 1962 in the Grand Valley area of Colorado and Utah were made during February 19 through March 3, and August 6 through 18, respectively. The February-March survey was conducted to coincide with a season wholly free from irrigation in the study area, but without flood flows in the river. The August survey coincided with a period of heavy irrigation activity and relatively low flow, as is indicated by the hydrograph in Figure 1.

The winter and summer surveys were each of two-week duration. Daily samples were taken six days each week at all main-stem stations and some drains. The samples from each six day period were composited for subsequent analysis.[?] The remaining drains and industrial and municipal effluents were sampled only one week. Individual daily samples were collected from each sampling station

1/ Reclamation Project Data, Grand Valley Project, U. S. Department of the Interior, Bureau of Reclamation.

2/ Directory of Manufacturers for the Colorado River Basin. DHEW, FHS, CRBWQCP.

during the sampling period. Samples were compiled on a weekly basis for each station. Tables I and II are lists of sampling stations and their descriptions for the February and August 1962 surveys. The river mileages listed were derived from Report BD-3 River Mileages for the Colorado River Basin.^{1/}

Figures 2 and 3 show the sampling stations for the two surveys. Figure 2 shows the survey area and main-stem sampling stations, while Figure 3 shows the irrigated areas of the Grand Valley as well as irrigation return drain sampling points for the August survey. During the August survey, the only main-stem stations sampled were GV-1 through GV-9. GV-4 was not sampled during February-March.

Chemical ^{analysis of} ~~determination~~ samples were made according to Standard Methods for the Examination of Water and Waste Water.^{2/}

Flow data from U. S. Geological Survey gaging stations were used to obtain flows at main-stem sampling points during each survey. At sampling points near gaging stations, the recorded flows were used, while at intermediate points, interpolation flows were used, taking into consideration known tributary flows in the river stretch. Irrigation drain flows for the August survey were obtained by Project personnel with the use of staff gages and flow meters.

PRESENTATION OF DATA:

Flows: During February 1962 total mean flows entering the grand valley area were as shown in Table III.

1/ River Mileages for the Colorado River Basin, Department of Health, Education and Welfare, U. S. Public Health Service, Colorado River Basin Project, Denver, Colorado, February 1962.

2/ Standard Methods for the Examination of Water and Waste Water, Eleventh Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation, 1960.

TABLE I - SAMPLING STATION LOCATIONS, MAIN STEM STATIONS

Station	Description	River Mile ^{b/}
GV ^{a/} 1	Colorado River at Cameo, Colo., USGS	1129.0
GV-2	Plateau Creek at mouth	1122.7
GV-3	Colo. River at bridge south of Clifton, Colo.	1107.2
GV-5	Gunnison River above confluence with Colo. River	1100.4
GV-7	Colo. River near Fruita, Colo. at State Highway 340 bridge crossing	1086.5
GV-8	Colo. River near Loma, Colo. at USPHS Water Quality station	1081.4
GV-9	Colorado River at Westwater, Utah	1056.2
GV-10	Colorado River above confluence with Dolores River	1025
GV-11	Dolores River above confluence with Colorado River	1023
GV-12	Colorado River above Moab, Utah, at US Highway 160 bridge crossing	991
GV-13	Colo. River 5 miles downstream of Station GV-12	986
GV-14	Colo. River approximately 2.0 miles below Texas Gulf Sulfur Company Potash Plant, approximately 17 miles below Moab, Utah	974

^{a/} GV- Grand Valley

^{b/} Colorado River mile from U. S. Mexican Border

TABLE II - SAMPLING STATION LOCATIONS, IRRIGATION DRAINS

<u>Station</u>	<u>Description</u>	<u>River Mile^{b/}</u>
I-1 ^{a/}	Drain near Climax Mill tailings ponds	1101.6
I-2	Drain to Gunnison River below AEC compound	1100.4
I-3	First drain below Grand Junction from road near river	1098.3
I-4	Second drain below Grand Junction from road near river	1098.2
I-5	Third drain below Grand Junction from road near river	1097.3
I-6	Wash above Persigo Wash from road near river	1093.1
I-7	Persigo Wash from road near river	1091.8
I-8	First Wash below Persigo Wash from road near river	1091.2
I-9	Second Wash below Persigo Wash from road near river	1090.9
I-10	Adobe Wash from road near river	1088.2
I-11	Little Salt Wash at Highway US 6-50	1084.9
I-12	Big Salt Wash at Highway US 6-50	1084.6
I-13	Reed Wash at Highway US 6-50	1082.4
I-14	Keifer Extension near mouth	1082.1
I-15	Mack Wash at Highway US 6-50	1073.4
I-16	East Salt Creek at Highway US 6-50	1073.4
I-17	Wash 1/4 mile west of East Salt Creek on Highway US 6-50	1073.4
I-18	West Salt Creek at Highway US 6-50	1073.4
I-19	Loma Drain 1 mile above mouth near Highway US 6-50	1082.4

TABLE II - SAMPLING STATION LOCATIONS, IRRIGATION DRAINS (continued)OTHER MAJOR WITHDRAWALS & ADDITIONS

Grand Valley Diversion Dam diversion	1122.8
Grand Valley Irrigation Company diversion	1113.6
Public Service Company hydro-power plant return	1113.5
Redland Power Canal return	1097.2

a/ I - Irrigation

b/ Colorado River Mile from U.S.-Mexican Border

TABLE III

MEAN FLOWS ENTERING GRAND VALLEY DURING FEBRUARY 1962

Colorado River near Cameo (GV ^a -1)	2,218 cfs
Plateau Creek (GV-2)	101 cfs
Gunnison River flow	<u>786 cfs</u>
Total	3,105 cfs

The flow at Westwater, Utah during the same period was 3,286 cfs. indicating an increase of 181 cfs., of which approximately 5 cfs. could be attributed to municipal and industrial contribution. The additional 176 cfs. constituted surface drainage and runoff within grand valley, and ground water contributions. The only appreciable flow contribution below Westwater was the Dolores River where 310 cfs. entered the Colorado River.

Mean flows entering the grand valley during the August survey were shown in Table IV.

TABLE IV

MEAN FLOWS ENTERING GRAND VALLEY DURING AUGUST 1962

Colorado River near Cameo (GV ^a -1)	3,198 cfs
Plateau Creek (GV-2)	60 cfs
Gunnison River Flow	<u>776 cfs</u>
Total	4,034 cfs

The mean total flow at Westwater, Utah, on leaving grand valley was 3,400 cfs.

The mean flows diverted for irrigation during the August survey are shown in Table V.

a/ G.V. - Grand Valley

TABLE V

MEAN FLOW DIVERTED FOR IRRIGATION USAGE DURING AUGUST 1962

Government Highline Canal	772 cfs
Orchard Mesa Irrigation Canal	150 cfs
Grand Valley Irrigation Co. Diversions	613 cfs
Diverted from Redland Power Canal	<u>60 cfs</u>
Total	1,595 cfs

During the August survey most of the accessible irrigation return drain flows were measured and sampled. However, there existed several large areas of irrigated land bordering the river from which the return flows were not measured or sampled. ^{from which flows were not measured and sampled} These areas were for the most part, irrigated land on the south side of the Colorado River and a large area on the north side of the river upstream of Grand Junction (See Figure 3). It is estimated that only 75 percent of the actual surface returns from irrigated lands were measured.

Total mean flows from measured irrigation returns was 508 cfs. Assuming only 75 percent of returns were measured, the total surface irrigation return flow would be 677 cfs. Since of the 4,034 cfs. flow available, only 1,595 cfs was applied to irrigation, this would leave 2,439 cfs to flow out of grand valley via the Colorado River. However, 3,400 cfs were actually passing Westwater, Utah, so 961 cfs is gained during the rivers' passage through grand valley. Of this 961 cfs, 677 cfs is from surface irrigation returns. Approximately 5 cfs is contributed by municipal and industrial enterprises (See Appendix A, part V) leaving 279 cfs which is contributed from ground water sources.

If it is assumed none of this 279 cfs from groundwater is attributable to irrigation processes, the total water consumed by irrigation is $1,595 \text{ cfs} - 677 \text{ cfs} = 918 \text{ cfs}$ or 57% of the water diverted for that purpose. This is a depletion rate of 0.022 acre feet of water/acre/day.

If it is assumed one-half of the 279 cfs is attributed to irrigation returns, the total return flow would be $677 \text{ cfs} + 140 \text{ cfs} = 817 \text{ cfs}$, leaving the flow depletion at $1,595 \text{ cfs} - 817 \text{ cfs} = 778 \text{ cfs}$, or 49% of the diverted water. This is a depletion rate of 0.018 acre feet/acre/day.

Figure 4 shows mean flows of the Colorado River in the Grand Valley area for both the February and August 1962 surveys.

Total Dissolved Solids:

Results presented in Figures 5 and 6 and summarized in Tables VI and VII indicates that total dissolved solids (TDS) or salinity of the Colorado River main-stem stretch from Cameo, Colorado to Westwater, Utah was affected by irrigation return flows originating in the Grand Valley area. Results in Table VI show the increase of TDS loading in this river stretch to be 2.56 million pounds per day more in August 1962, during the irrigation season, than in February 1962, when there was no irrigation in the area.

Results in Table VII show that of this 2.56 million pounds per day TDS increase, 1.94 million pounds per day results directly from solids added by irrigation return flows. Results in Table VII also show that the TDS being conveyed to the Colorado River by the Gunnison River during August 1962 was approximately 1 million pounds per day more than during February 1962. This increased TDS loading in the Gunnison River resulted in part from solids added to it by return flows from the 264,000 acres of land irrigated in the Gunnison

9.46
4.90
2.56

Repeated

omit

TABLE VI

**TOTAL DISSOLVED SOLIDS SUMMARY RESULTS FOR
FEBRUARY-AUGUST 1962 PROJECT SURVEYS IN GRAND VALLEY**

Cameo, Colorado - Westwater, Utah Reach of Colorado River				
Location	February		August	
	Concentrations Mg/l	Weights 10⁶ lbs/day	Concentrations Mg/l	Weights 10⁶ lbs/day
Cameo	553	6.6 } 6.7	471	8.12 } 9.46
Westwater	764	13.5	959	17.58
Westwater, Utah - Moab, Utah Reach of Colorado River				
Westwater	764	13.5	--	--
Moab	871	17.1	--	--

TABLE VII

SOURCES AND APPROXIMATE WEIGHTS OF TOTAL DISSOLVED SOLIDS
ADDED BY EACH SOURCE TO COLORADO RIVER IN GRAND VALLEY AREA DURING
FEBRUARY AND AUGUST 1962

Cameo, Colorado - Westwater, Utah Reach of Colorado River		
Source	February	August
	Weight (10^6 lbs/day)	Weight (10^6 lbs/day)
Plateau Cr.	0.22	0.16 —?
Gunnison R.	4.12	5.16
Municipal & Industrial	0.03	0.03
Irrigation Re- turns	--	1.94 — BASED ON 75% FACTOR?
Undetermined	2.53 6.90	2.18 9.47
Westwater, Utah - Moab, Utah Reach of Colorado River		
Dolores R.	3.0	--
Undetermined	0.6	--

Results in Table VII show that of this 2.56 million pounds per day TDS increase, 1.94 million pounds per day results directly from solids added by irrigation return flows. Results in Table VII also show that the TDS being conveyed to the Colorado River by the Gunnison River during August 1962 was approximately 1 million pounds per day more than during February 1962. This increased TDS loading in the Gunnison River resulted in part from solids added to it by return flows from the 264,000 acres of land irrigated in the Gunnison River Basin. (The Gunnison River Basin is covered in another section of this report.)

By comparing the increased loadings in the reach of the Colorado River between Cameo, Colorado and Westwater, Utah during the months of February and August 1962, as shown in Table VIII, a good agreement of results for these two periods was apparent. This comparison also made apparent the effect of irrigation return flows on Colorado River water quality.

TABLE VIII

FEBRUARY-AUGUST 1962 COMPARISON OF INCREASE IN TDS LOADING OF THE COLORADO RIVER FOR THE REACH BETWEEN CAMEO, COLORADO, AND WESTWATER, UTAH

FEBRUARY ¹	AUGUST
6.90×10^6 lbs/day	9.46×10^6 lbs/day
1.94×10^6 lbs/day ²	--
$+ 1.04 \times 10^6$ lbs/day ³	--
9.88×10^6 lbs/day	9.46×10^6 lbs/day

1. The increase attributed to irrigation return flows were added to increase for February to make condition similar for comparison.
2. Increase attributed to irrigation returns to Colorado River present in August and not in February.
3. Increase attributed to irrigation returns to Gunnison River, present in August and not in February.

During February 1962 the principal sources causing TDS increase in the Colorado River reaches from Cameo, Colorado to Westwater, Utah, and Westwater, Utah to Moab, Utah, were tributary additions. (Figures 5 and 6). The Gunnison River was the major contributor for the Cameo to Westwater reach (Table VII), and the Dolores River was the major contributor for the Westwater to Moab reach.

In August 1962, return flows from irrigated lands in grand valley contributed substantial amounts of TDS (1.94 million lbs/day) to the Colorado River in the reach from Cameo to Westwater. Tributary contributions of TDS were present during both February and August. (See Figures 5 and 6, and Table VII). The total dissolved solids in surface returns draining irrigated lands in grand valley was approximately 6.34 million lbs/day. Another 2.18 million lbs/day was added to the river from undetermined sources in this reach. However, some of the solids returned to the river in irrigation return waters had been originally diverted from the river. By using the diverted flow and TDS concentration for the diverted water, a figure of 4.40 millions lbs/day was computed for solids diverted in the irrigation water. The difference in TDS diverted and TDS returned would be in the range of 1.96 million lbs/day to 4.12 million lbs/day, depending on whether none or all of the undetermined increment in TDS added to the river as it flows through the grand valley area is attributed to irrigation. It is known that part of this increment in TDS resulted from irrigation because it was estimated that only 75 percent of the irrigation return flows were measured during the August 1962 survey. This range of 1.96 million lbs/day to 4.12 million lbs/day

would amount to from 22.8 lbs/acre/day to 48.5 lbs/acre/day of TDS for the estimated 85,000 acres of irrigated land in the study area. This range agrees very well with USGS estimates of 5.6 tons/acre/year presented in their Interim Progress Report.^{1/}

The principal sources of salinity as identified during the Project's February and August 1962 surveys were; 1. tributary contributions making up approximately 62 percent of the total TDS loadings increase during February, and 56 percent during August, 2. Undetermined sources making up approximately 37 percent of the total TDS loadings increase during February and 22 percent during August, 3. irrigation return flows making up approximately 21 percent of total TDS loading increase during August.

Municipal and industrial contributions to the TDS increase in the Colorado River as it flows through grand valley were very small compared to the other sources, making up less than one percent of the total TDS loading increase in either February or August.

Major Chemical Constituents Making Up Total Dissolved Solids

Sulfates: Figures 7 and 8 and Tables IX and X show sulfate data for the Project's February and August 1962 surveys in the grand valley area.

In February 1962, sulfate loadings in the Colorado River increased from 1.60 million lbs/day at Cameo, Colorado to 5.90 million lbs/day at Westwater, Utah, an increase of 4.32 million lbs/day.

In August 1963 sulfates increased from 2.0 million lbs/day to 7.9 million lbs/day in this river stretch. (See Table IX). Sulfates accounted for 63 percent of the TDS increase in this reach of the Colorado during both

TABLE IX

**SUMMARY SULFATE RESULTS FOR FEBRUARY-AUGUST
1962 SURVEYS IN GRAND VALLEY**

Cameo, Colorado - Westwater, Utah Reach of Colorado River				
Location	February		August	
	Concentrations Mg/l	Weights 10 ⁶ lbs/day	Concentrations Mg/l	Weights 10 ⁶ lbs/day
Cameo	135	1.61	114	1.96
Westwater	335	5.93	429	7.87

Westwater, Utah to Moab, Utah Reach of Colorado River				
Westwater	335	5.93	--	--
Moab	340	6.67	--	--

TABLE X

**SOURCES AND APPROXIMATE WEIGHTS OF SULFATES ADDED BY EACH SOURCE
TO THE COLORADO RIVER IN GRAND VALLEY AREA DURING
FEBRUARY AND AUGUST 1962.**

Cameo, Colorado to Westwater, Utah Reach of Colorado River		
Source	February	August
	(Weight (10 ⁶ lbs/day))	Weight (10 ⁶ lbs/day)
Plateau Cr.	0.05	0.04
Gunnison River	2.29	2.55
Irrigation Returns	--	2.03
Undetermined	1.97	1.30
Westwater, Utah to Moab, Utah Reach of Colorado River		
Dolores River	0.68	--
Undetermined	0.06	--

February and August 1962. The TDS increases for this river reach were 6.9 million lbs/day and 9.46 million lbs/day for February and August respectively.

Table X shows the major sources affecting the increase in sulfates. One important source was the Gunnison River which contributed 2.29 million lbs/day or 52 percent of the total sulfates increase of 4.30 million lbs/day during February and 2.55 million lbs/day or 43 percent of total increase of 5.90 lbs/day in August. Another important source present in August, but not in February, was irrigation return flows. Sulfate increases of 3.21 million lbs/day to 4.19 million lbs/day was attributed to return flows from irrigation in the grand valley area. However, since 1.18 million lbs/day of sulfates were diverted from the River in irrigation water, the net contribution of sulfates from irrigation returns was in the range of 2.03 million lbs/day to 3.33 million lbs/day or from 23.9 to 39.2 pounds/acre/day. These values were expressed as a range rather than a specific value because there was 1.30 million lbs/day of sulfates being added to the river from undetermined sources. One of these sources was irrigation return flows not sampled or measured because of insufficient personnel to sample all of the irrigation drains in the study area. The increase in sulfate in the Colorado River stretch between Westwater and Moab of 0.74 million lbs/day during February 1962 was almost entirely due to Dolores River contributions. No other sources of sulfate contributions to the river appeared significant when compared to the above mentioned during these surveys.

Chlorides: In February 1962 results show (Tables XI and XII) that the Dolores River was the only significant contribution of chlorides (1.10 million lbs/day) to the Colorado River in its reach from Cameo, Colorado to Moab, Utah. During August 1962 the chlorides entering grand valley

TABLE XI

**SUMMARY CHLORIDE RESULTS FOR FEBRUARY - AUGUST 1962
SURVEYS IN GRAND VALLEY**

Cameo, Colorado to Westwater, Utah Reach of Colorado River				
Location	February		August	
	Concentrations Mg/l	Weights 10^6 lbs/day	Concentrations Mg/l	Weights 10^6 lbs/day
Cameo	136	1.63	101	1.91
Westwater	106	1.88	91	1.67

Westwater, Utah to Moab, Utah Reach of Colorado River				
Westwater	106	1.88	--	--
Moab	147	2.89	--	--

TABLE XII

**SOURCES AND APPROXIMATE WEIGHTS OF CHLORIDES ADDED BY EACH SOURCE
TO THE COLORADO RIVER IN GRAND VALLEY AREA DURING
FEBRUARY AND AUGUST 1962**

Cameo, Colorado to Westwater, Utah Reach of Colorado River		
Source	February	August
	Weight (10^6 lbs/day)	Weight (10^6 lbs/day)
Plateau Cr.	0.004	0.003
Gunnison River	0.062	0.070
Irrigation Returns	--	--
Undetermined	0.186	--
Westwater, Utah to Moab, Utah Reach of Colorado River		
Dolores River	1.10	--
Undetermined	0.90	--

via the Colorado River, Gunnison River and Plateau Creek exceeded the chlorides leaving the area via the Colorado River at Westwater, Utah. Results in Tables XI and XII indicate that 1.91 million lbs/day enter the area via the Colorado River at Cameo, 0.07 million lbs/day via the Gunnison River, and 0.03 million lbs/day via Plateau Creek for a total chloride loading in the Colorado River of 1.98 million lbs/day, but only 1.67 million lbs/day was leaving the area via the Colorado River at Westwater, Utah. If this 0.31 million lbs/day chlorides loss was assumed lost on the irrigated land in grand valley, then there was an approximate chloride build up in this land of 3.8 lbs/acre/day.

Bicarbonates: August 1962 chemical results (Appendix A, Parts III and IV) indicated that there was also a loss of bicarbonates from Colorado River water as it flows through grand valley. Bicarbonate loadings entering grand valley via Colorado River at Cameo, the Gunnison River, and Plateau Creek, totaled 3.51 million lbs/day. This loading decreased to 3.00 million lbs/day at Westwater, Utah. If this 0.51 million lbs/day bicarbonate loss was assumed lost through irrigation, then there was a 6.0 lbs/acre/day build-up of bicarbonates in grand valley lands along with the indicated chloride build-up.

Sodium: A comparison of the February 1962 sodium results with August 1962 results (see Table XIII) indicates no difference in sodium build-up in the Colorado River as it flows through this area. In February sodium increased 0.65 million lbs/day in the reach between Cameo and Westwater. There was a similar increase in August.

As shown in Table XIV the major sources of sodium increase in the Colorado River reach from Cameo, Colorado, to Moab, Utah were the Gunnison and Dolores Rivers, and an substantial undetermined amount originating in this reach.

TABLE XIII

SUMMARY SODIUM RESULTS FOR FEBRUARY - AUGUST 1962
SURVEYS IN GRAND VALLEY

Cameo, Colorado to Westwater, Utah Reach of Colorado River				
Location	February		August	
	Concentrations Mg/l	Weights 10 ⁶ lbs/day	Concentrations Mg/l	Weights 10 ⁶ lbs/day
Cameo	87	1.04	82	1.41
Westwater	116	2.05	113	2.06

Westwater, Utah to Moab, Utah Reach of Colorado River				
Westwater	116	2.05	--	--
Moab	138	2.70	--	--

TABLE XIV

SOURCES AND APPROXIMATE WEIGHTS OF SODIUM ADDED BY EACH SOURCE
TO THE COLORADO RIVER IN GRAND VALLEY AREA DURING
FEBRUARY AND AUGUST 1962

Cameo, Colorado to Westwater, Utah Reach of Colorado River		
Source	February	August
	Weight (10 ⁶ lbs/day)	Weight (10 ⁶ lbs/day)
Plateau Cr.	0.03	0.03
Gunnison River	0.40	0.41
Irrigation Returns	--	--
Undetermined	0.58	0.22
Westwater, Utah to Moab, Utah Reach of Colorado River		
Dolores River	0.72	--
Undetermined	0.07	--

Hardness (Calcium and Magnesium expressed as calcium carbonate):

Comparing February and August 1962 hardness results shown in Table XV for the Colorado reach from Cameo to Westwater, it was noted that there was 2.05 million lbs/day more hardness increase in this river stretch during August than during February. It was assumed that irrigation caused this difference since there was irrigation during August but none during February, and since other conditions were approximately the same during both periods.

The Gunnison River was one of the primary sources contributing to hardness build-up in the Cameo to Westwater reach of the Colorado River (see Figures 9 and 10). It contributed 79 percent of the total hardness increase for this reach during February 1962 and 54 percent during August 1962. (See Tables XV and XVI). Another important source contributing hardness to the river in this reach during August 1962 was irrigation return flows. Measured surface irrigation return flows contained 3.33 million lbs/day of hardness. Since the amount of hardness diverted from the river in irrigation water was 2.06 million lbs/day, the net hardness from irrigation was in the range of 1.27 million lbs/day to 2.40 million lbs/day, or approximately 15 to 28 lbs/acre/day, depending on the amount of the 1.13 million lbs/day of undetermined source of hardness, resulted from irrigation. Downstream from Westwater to Moab, Utah the Dolores River was the only major source identified that contributed to Colorado River hardness. However, results showed a substantial hardness increase (1.64 million lbs/day) from other sources which were not identified in this stream reach.

The contributions of various chemical constituents to the total dissolved solids build up in the Colorado River reach from Cameo to Westwater are shown in Table XVII. Only primary chemical constituents were considered.

TABLE XV

SUMMARY HARDNESS^{a/} RESULTS FOR FEBRUARY - AUGUST 1962
SURVEYS IN GRAND VALLEY

Cameo, Colorado to Westwater, Utah Reach of Colorado River				
Location	February		August	
	Concentrations Mg/l	Weights 10 ⁶ lbs/day	Concentrations Mg/l	Weights 10 ⁶ lbs/day
Cameo	237	2.88	218	3.76
Westwater	326	5.76	474	8.69

Westwater, Utah to Moab, Utah Reach of Colorado River				
Westwater	326	5.76	--	--
Moab	404	8.28	--	--

TABLE XVI

SOURCE AND APPROXIMATE WEIGHTS OF HARDNESS^{a/} ADDED BY EACH SOURCE
TO THE COLORADO RIVER IN GRAND VALLEY AREA DURING
FEBRUARY AND AUGUST 1962

Cameo, Colorado to Westwater, Utah Reach of Colorado River		
Source	February	August
	Weight (10 ⁶ lbs/day)	Weight (10 ⁶ lbs/day)
Plateau Cr.	0.09	0.08
Gunnison R.	2.27	2.45
Irrigation Returns	--	1.27
Undetermined	0.52	1.33

Westwater, Utah to Moab, Utah Reach of Colorado River		
Dolores River	0.88	--
Undetermined	1.64	--

^{a/} Calcium and Magnesium hardness expressed as calcium carbonate (CaCO₃)

TABLE XVII

MAJOR CHEMICAL CONSTITUENT BREAKDOWN OF TOTAL DISSOLVED SOLIDS (TDS)
BUILD UP IN THE COLORADO REACH FROM CAMEO, COLORADO TO WESTWATER, UTAH

Increase for Cameo, Colorado to Westwater, Utah Reach of Colorado R.				
		February	August	
TDS		6.90×10^6 lbs/day	9.46×10^6 lbs/day	
Major Chemical Constituents Making Up TDS	Weight (10^6 lbs/day)	% of Total TDS	Weight (10^6 lbs/day)	% of Total TDS
Sulfates	2.00	29.0	5.91	63.0
Chlorides	0.25	3.6	b/	--
Sodium	1.01	14.6	0.65	6.9
Hardness ^{a/}	2.88	42.0	4.16	52.0

^{a/} Hardness is calcium and magnesium hardness expressed as calcium carbonate, and values presented are values for hardness as calcium carbonate

^{b/} There was a 0.24×10^6 lbs/day decrease or loss of chlorides here rather than an increase.

General Discussion:

The purpose of the August survey was to investigate the effect irrigation return flows had on Colorado River water quality. The Westwater, Utah, to Moab, Utah stretch of the Colorado River main-stem was not investigated during the August 1962 survey because it received no substantial return flows from irrigated land. Irrigated land along this river stretch was in the range of approximately one hundred acres.

There appeared many times in the data presentation section the term "undetermined source". This term was used because there was an increase of chemical solids in the Colorado River that couldn't be attributed directly to a particular source with data obtained during the project's surveys. The data revealed the increase, but was not sufficient to pinpoint the specific sources. This chemical solids increase was assumed to have resulted from one or all of several possible sources such as ground water infiltration, return irrigation flows not measured, material picked up and dissolved from the river channel itself, small tributary additions not measured, and accumulating errors occurring in flow measurements, sample collection and analyses, and data evaluations. Since it was known that only about 75 percent of the irrigation return flows were measured, it was assumed that irrigation return flows and small tributary flows not measured were the primary contributor of this undetermined increase of chemical solids.

The decreases in TDS appearing in figures showing results of chemical loadings in the Colorado River were caused by flow being diverted, primarily for irrigation, from the main-stem of the Colorado. The points of diversions were designated on these figures. The water diverted reduced the flow of the River and also reduced the solids and chemical loadings being transported by the river.

The data showed that the Gunnison River contributed more solids to the Colorado River during August 1962 than during February 1962. The data indicates that the added solids in the Gunnison River during August 1962 resulted from irrigation return flows. There was approximately 264,000 acres of farm land being irrigated in the Gunnison River basin during August. The Gunnison River eventually received all of the return flows from this irrigated land, and transported these return flows to the Colorado River in the grand valley area. There were no irrigation activities in the Gunnison River Basin during February 1962 and, therefore, no irrigation return flows.

Complete chemical results for the February and August 1962 surveys in grand valley area are included in Appendix A.